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A

AAO Abbreviation for ► *Anglo-Australian Observatory*.

AAS Abbreviation for ► *American Astronomical Society*.

AAT Abbreviation for ► *Anglo-Australian Telescope*.

AAVSO Abbreviation for ► *American Association of Variable Star Observers*.

Abell Catalogue A catalog of 2712 rich clusters of galaxies drawn up by George Abell from the ► *Palomar Observatory Sky Survey*. With the original publication in 1958 he demonstrated that there are two types of galaxy cluster: a compact type that is regular in shape and a more spread out, irregular type. In 1989 a revised version was published under the title *A Catalogue of Rich Clusters of Galaxies*, which includes 4073 galaxies and covers the whole sky. Southern data were obtained from the ► *United Kingdom Schmidt Telescope*.

aberration (1) An imperfection in the imaging properties of a lens or mirror. The main aberrations are ► *chromatic aberration*, ► *spherical aberration*, ► *coma*, ► *astigmatism*, ► *curvature of the field* and ► *distortion*.

aberration (2) An apparent displacement in the observed position of a star. It is a result of the finite speed of the light travelling from the star, combined with the motion through space of the observer on Earth relative to the star, etc. Aberration arising from the Earth's orbital motion around the Sun is termed *annual aberration*. The much smaller component that results from the daily rotation of the Earth is called *diurnal aberration*.

ablation The erosion of a surface through a process such as vaporization or friction. For example, when a meteoroid enters a planetary atmosphere, ablation occurs because of friction between the surface and the gas molecules in the atmosphere.

absolute luminosity A measure of the actual rate of energy output of a star or other celestial object as opposed to the ► *apparent luminosity*, which depends on the distance to the object.

absolute magnitude (symbol *M*) For a star, the ► *magnitude* the star would appear to have if it were at a standard distance of 10 ► *parsecs*. Absolute magnitudes are a method of comparing the actual luminosities of stars on an arbitrary scale.

absolute reference frame

For an asteroid or comet, the absolute magnitude is the ► *apparent magnitude* it would have at zero ► *phase angle* and at a distance of 1 AU from both the Sun and Earth.

absolute reference frame A ► *reference frame* representing the universe as a whole, which is taken to be stationary. It is assumed that the ► *cosmic background radiation* is an absolute frame of reference.

absolute zero The point at which all molecular motion ceases and so, theoretically, the lowest possible temperature. It is the zero point of the Kelvin temperature scale used in science. The equivalent on the Celsius scale is $-273.16\text{ }^{\circ}\text{C}$.

absorption The process by which the intensity of radiation decreases as it passes through a material medium. The energy lost by the radiation is transferred to the medium. Many physical processes observed in astronomy involve absorption, including absorption of light from celestial objects in the Earth's atmosphere (► *atmospheric extinction*), ► *interstellar extinction* and absorption within the gaseous layers of a star, resulting in an ► *absorption line* spectrum.

absorption coefficient A measure of the ability of a material to absorb radiation that passes through it. A high absorption coefficient indicates that the material absorbs radiation effectively. The absorption coefficient may depend strongly on the wavelength of the radiation, the temperature and other physical conditions.

absorption line A sharp dip in intensity over a narrow wavelength range in a ► *continuous spectrum*. In a spectrum produced by a typical ► *spectrograph*, in which the light passes through a narrow slit before being dispersed, absorption lines have the appearance of dark lines cutting across at right angles to the direction of dispersion.

Absorption lines are a characteristic of the spectra of the majority of stars. In the case of the Sun, they are known as ► *Fraunhofer lines*. Atoms are able to absorb radiation at a number of precise wavelengths. The wavelengths at which absorption occurs are different for each chemical element, making it possible to identify the elements present in a star, or other celestial body, by analyzing which spectral lines are present. The strength of the lines can be used to deduce the abundance of the elements, though not directly since the temperature, density and other physical circumstances greatly influence the strength of absorption lines in a spectrum. ► *emission line*.

absorption line spectrum A ► *continuous spectrum* in which narrow ► *absorption lines* can be seen.

accretion disk

absorption nebula A dark interstellar cloud that absorbs the light from bright objects behind it. Absorption nebulae range in size from small ► *globules* to large clouds visible to the unaided eye, such as the ► *Coalsack* in the southern Milky Way. Absorption nebulae contain both dust and gas, and the temperatures in them are low enough for simple molecules to form. Much of the knowledge about these nebulae comes from observations of infrared and radio radiation, which, unlike visible light, can pass through them. Such observations have confirmed that the initial stages of star formation take place in dark nebulae. ► *molecular cloud*.

absorption spectrum A ► *continuous spectrum* in which absorption features of some kind are seen. They may be ► *absorption lines* or ► *diffuse interstellar bands*, for example. ► *band spectrum*.

abundance The relative number of atoms of a particular element or isotope in the chemical composition of a single substance or object, or in a structure such as the solar system, or in the universe as a whole.

acceleration The rate at which velocity changes with time. Any mass with a net force acting on it undergoes acceleration. The *acceleration due to gravity* (symbol g) is the acceleration experienced by an object falling freely at a body's surface, pulled by the force of gravity. On Earth, the average value is around 9.8 m/s^2 .

accretion The process by which small particles of material coalesce, or accumulate on a larger mass, under the influence of their mutual gravitational attraction or as a result of chance collisions, thus gradually creating larger bodies.

accretion disk A disk structure that forms around a spinning object, such as a star or ► *black hole*, when material is drawn into its gravitational field.

As stars evolve they enter a giant phase, when their size increases dramatically. In a binary system, the gravitational pull of the companion star on the bloated envelope of the giant may be stronger than the force holding the giant star and its envelope together. Under these circumstances, material flows across from one star to the other where an accretion disk forms. The presence of an obscuring accretion disk may cause the star to be variable, as with ► *Beta Lyrae stars*, and this may be detectable from features in the spectrum.

If the companion is spinning rapidly, as will a collapsed star (a ► *white dwarf*, ► *neutron star* or black hole), the kinetic energy of the material falling onto the swirling accretion disk is turned into heat, and X-rays are produced.

A mechanism of this kind is thought to be responsible for the production of X-rays in objects such as ► *Cygnus X-1*. ► *Roche lobe*, SS433.

ACE Abbreviation for ► *Advanced Composition Explorer*.

Achernar (Alpha Eridani) The brightest star in the constellation Eridanus. The name, which is of Arabic origin, means ‘the end of the river’ and the star marks the southern extremity of the constellation at a declination of -57° . Achernar is a ► *B star* of magnitude 0.5. ► Table 3.

Achilles Asteroid 588, diameter 116 km. Discovered by M. Wolf in 1906, it was the first of the ► *Trojan asteroids* to be identified.

achondrite A type of stony ► *meteorite* that crystallized from molten rock. The name indicates the absence of ► *chondrules* in this type of meteorite, in contrast with ► *chondrites*. Compared with chondrites, they have a greater abundance of calcium-rich minerals and much less of the metal and sulfide minerals.

achromatic lens (achromat) A composite lens, made up of two elements of different kinds of glass, designed to reduce ► *chromatic aberration*. ► *apochromat*.

Acidalia Planitia A dark plain in the northern hemisphere of Mars, formerly known as Mare Acidalia.

acoustic waves Pressure waves in a fluid. Acoustic waves can propagate through the gaseous layers of stars (including the Sun). They are produced where pressure is the dominant force restoring the balance when there is a small displacement of the gas.

acronical observation An observation shortly after sunset of a star that is just rising or just setting. Such observations of bright stars (e.g. Sirius) were used in ancient times for keeping track of the seasons. ► *heliacal rising*.

Acrux (Alpha Crucis) The brightest star in the constellation Crux. Appearing to the unaided eye as a white star of magnitude 0.9, it is a visual double, the two components being ► *B stars* of magnitude 1.4 and 1.9. The separation is 4.4 arc seconds. ► Table 3.

actinometer An instrument for measuring the intensity of solar radiation. Such instruments are now more usually called pyrheliometers.

active galactic nucleus (AGN) The central region of an active galaxy in which exceptionally large amounts of energy are being generated from a source other than the normal output of individual stars. This is a common characteristic of various types of object that have been classified differently according to their appearance and the nature of the radiation they emit.

active region

► *Quasars*, ► *Seyfert galaxies*, ► *radio galaxies*, ► *N galaxies* and ► *blazars* are all manifestations of the same phenomenon. In every case, the source of power appears to be concentrated within the nucleus; the only mechanism known that can account for the huge amount of energy observed is the presence of a supermassive ► *black hole*, into which matter is falling with the release of gravitational energy. Variability over relatively short timescales shows that the powerhouse must be concentrated in a small region of space.

Evidence that a highly energetic process is occurring comes both from the sheer luminosity of distant objects like quasars and from the existence of jets of material ejected from the central regions. The giant elliptical galaxy M87, which is also a strong radio and X-ray source, has a spectacular jet consisting of a series of knots of hot gas. With radio galaxies, most of the energy comes from two gigantic clouds of ionized gas, one either side of the galaxy from which it seems they have been ejected.

The differences between the various kinds of AGN can be accounted for by the level of their power output and the angle from which they are viewed. The black hole is surrounded by a ring of dust and gas at right angles to the jets. In radio galaxies the ring is edge-on, obscuring the light from the black hole. Blazars are thought to have their jets pointing along the line of sight to Earth. In quasars and Seyfert galaxies, the ring is oriented so that the light emitted by the accretion disk around the central black hole is visible.

active optics A method of maintaining a highly accurate optical surface in a reflecting telescope by means of a computer-controlled feedback system that continually monitors the quality of the image and uses the information to adjust a motorized support system under the mirror.

The development of this technique means that mirrors can be made from thinner, less massive blanks that can be supported in a lighter structure. If the mirror is flexible enough, problems such as ► *spherical aberration* and ► *astigmatism* can be greatly reduced by applying constant forces at a large number of positions (perhaps fifty or more) on the back of the mirror. Variations in the forces on the mirror, such as the flexure under gravity as the telescope moves, can be corrected at intervals as short as a few minutes.

The term has also been used to describe the technique now more commonly called ► *adaptive optics*.

active region A region in the outer layers of the Sun where ► *solar activity* is taking place. Active regions develop where strong magnetic fields emerge from the subsurface layers. A variety of features may be observed in the ► *photosphere*,

active Sun

the ► *chromosphere* and the ► *corona*. Phenomena such as ► *sunspots*, ► *plages* and ► *flares* are evidence of an active region. Radiation is enhanced over the whole spectrum, from X-rays to radio waves, though in sunspots the localized decrease in temperature reduces the visual brightness. There is a large variation in the size and duration of active regions: they may last from several hours up to a few months. Electrically charged particles and the enhanced ultraviolet and X-radiation from active regions affects the interplanetary medium and the upper atmosphere of the Earth.

active Sun The Sun during periods of ► *solar activity*.

activity index Any one of a number of indicators of the level of ► *solar activity* at a given time. Indices used to measure solar activity include the ► *Wolf sunspot number*, the total area covered by ► *sunspots* on the visible hemisphere, and a K-plage index derived from the areas and brightness of ► *plages*. In addition, the total radio and X-radiation from the Sun are also regarded as indices of solar activity.

adaptive optics A technique for improving the quality of the image produced by an astronomical telescope in which the optical system compensates for changes in the quality of ► *seeing* – constantly varying distortions produced by refraction in the Earth's atmosphere. The distortion is corrected by the rapid bending of a small, very thin mirror placed a short distance before the focus. To be effective, the system needs an image sensor, a microprocessor and actuators to apply forces to the thin mirror, all of which must have response times shorter than a hundredth of a second.

Adhara (Epsilon Canis Majoris) The second-brightest star, after Sirius, in the constellation Canis Major. It is a giant ► *B star* of magnitude 1.5 and has an eighth magnitude companion. The Arabic name means 'the virgins'. ► Table 3.

Adonis Asteroid 2101, diameter 2 km, discovered by E. Delporte in 1936. It is a member of the ► *Apollo* asteroid group and came within 2 million km of the Earth in 1937, but was then lost until recovered in 1977 following recomputation of its orbit.

Adrastea A small satellite of Jupiter (number XV), discovered by David Jewitt in 1979. ► Table 6.

ADS Abbreviation for ► *Aitken Double Star Catalogue*.

Advanced Composition Explorer (ACE) A US spacecraft, launched in August 1997, carrying nine scientific instruments for determining the isotopic and elemental composition of the solar ► *corona*, the ► *interplanetary medium*, the local ► *interstellar medium* and galactic material. It was placed in solar orbit, at

one of the Earth's ► *Lagrangian points*, 1.5 million km (1 million miles) nearer the Sun than the Earth, to maintain an almost constant position relative to the Earth. ACE was expected to operate for between two and five years.

Advanced Electro-Optical System Telescope (AEOS Telescope) A US Air Force 3.67-m telescope at the ► *Air Force Maui Optical Station*. It is the world's largest telescope capable of tracking rapidly moving objects, such as satellites.

Advanced X-ray Astrophysics Facility (AXAF) ► *Chandra X-ray Observatory*.

advection (1) The transfer of material or a physical property, such as heat, through horizontal motion in a planetary atmosphere.

advection (2) The transfer of material directly from one star to another in an interacting binary system rather than via an ► *accretion disk*. Radiation is produced less efficiently than when an accretion disk is involved.

AEOS Telescope Abbreviation for ► *Advanced Electro-Optical System Telescope*.

aerobot A scientific experiment package deployed in a planetary atmosphere by means of a balloon.

aerobraking The controlled use of atmospheric drag to reduce the speed of a satellite and modify its orbit. The technique was used, for example, to place ► *Mars Global Surveyor* in its operational orbit around Mars.

aero lens A camera lens designed and manufactured for aerial survey work.

aerolite An alternative, largely obsolete name for a stony ► *meteorite*.

aeronomy The study of the physical and chemical processes in the upper atmosphere of the Earth, or of other planets.

aerosol A suspension of particles in a gas, such as mist in an atmosphere.

Ae star An ► *A star* that shows ► *emission lines* of hydrogen superimposed on the ► *absorption lines* in its spectrum. Such emission may arise from interactions between the two members of a close binary system.

aether Alternative spelling of ► *ether*.

AGB Abbreviation for ► *asymptotic giant branch*.

Agena An alternative name for the star ► *Hadar*.

AGK Abbreviation for the star catalog *Astronomische Gesellschaft Katalog*. The first project, for cataloging all stars between declinations -2° and $+80^\circ$ down to ninth magnitude, was initiated by F. W. Argelander in 1867. Seventeen observatories participated and the fifteen volumes of AGK1 listed 150 000 stars. An extension to declination -23° published in 1887 contained a further 50 000 stars. A second version was started in the 1920s, using photography rather than visual observations, and was published in 1951–58.

Measurements of ► *proper motions* were included in the 1975 third version,

AGK3. AGK positions are accurate positions, calculated relative to fundamental stars. ► *fundamental catalog*.

AGN Abbreviation for ► *active galactic nucleus*.

Ahnighito meteorite The largest ► *meteorite* displayed in any museum, housed at the Hayden Planetarium in New York City. It was found by Robert Peary in Greenland in 1897 and is of the iron type. Its weight is 31 tonnes.

Air Force Maui Optical Station A US military facility in Hawaii which is the location of the ► *Advanced Electro-Optical System Telescope* also used for astronomical research.

airglow The light produced and emitted by the Earth's own atmosphere, excluding ► *thermal radiation*, ► *aurorae*, lightning and ► *meteor* trains. The spectrum of the airglow ranges from 100 nm to 22.5 μm . A major component is an emission line due to oxygen at 558 nm, which originates in a layer 30 to 40 km thick at a typical height of 100 km (60 miles). From space, the airglow appears as a ring of greenish light around the Earth.

air shower A proliferation of high-energy charged particles in the atmosphere, triggered by the collision of a ► *cosmic ray* particle with an atomic nucleus in the atmosphere. The first collision produces a number of secondary particles, all of which have considerable energy and may subsequently undergo further collisions.

Airy disk The smallest image a particular telescope can make of a point source of light, such as a star. Diffraction as the light passes through the telescope aperture causes the image of even a point source to have a finite size. The diameter of the Airy disk is smaller for larger apertures. In practice, because of turbulence in the Earth's atmosphere, which distorts and enlarges the perceived image, it is rarely possible to achieve images as small as the Airy disk unless ► *active optics* are employed.

Aitken Double Star Catalogue (ADS) A catalog of over 17 000 binary stars compiled by Robert G. Aitken and published in 1932. Its formal title is *New General Catalogue of Double Stars*.

AI Velorum star ► *Delta Scuti star*.

AJ A common abbreviation for the ► *Astronomical Journal*.

Alauda Asteroid 702, diameter 202 km, discovered by J. Helffrich in 1910.

albedo The proportion of the light falling on a body or surface that is reflected. Albedo may be expressed as a fraction between 0 (perfectly absorbing) and 1 (perfectly reflecting) or as an equivalent percentage. ► *Bond albedo*, *geometric albedo*, *hemispherical albedo*.

albedo feature A feature on the surface of a planet distinguished by how light or dark it appears. Albedo features do not necessarily correspond to topographic features, but are due to differences in the composition or physical nature of surface materials.

Albert Asteroid 719, diameter 2.6 km. It was discovered by J. Palisa in 1911, when it made a close approach to the Earth. It was subsequently lost for almost 80 years, but recovered by chance in May 2000.

Albireo (Beta Cygni) The second brightest star in the constellation Cygnus. Visual observers regard it as one of the most beautiful double stars. The primary star is a yellow-orange \blacktriangleright *K star*, a giant of magnitude 3.2, and its companion a bluish \blacktriangleright *B star* of magnitude 5.4. The two components are separated by 35 arc seconds.

Alcaid Alternative form of \blacktriangleright *Alkaid*.

Alcor (80 Ursae Majoris) The fourth magnitude \blacktriangleright *A star* that forms a naked-eye double with \blacktriangleright *Mizar* in the constellation Ursa Major. The two stars are separated by 11.5 arc minutes on the sky and 10 light years in space.

Alcyone (Eta Tauri) The brightest member of the \blacktriangleright *Pleiades* star cluster in the constellation Taurus. The name is that of the daughter of Atlas and Pleione in Greek mythology. Alcyone is a \blacktriangleright *B star* of magnitude 2.9.

Aldebaran (Alpha Tauri) The brightest star in the constellation Taurus. Its Arabic name means ‘the follower’. Aldebaran is a giant \blacktriangleright *K star* of magnitude 0.9. Although it appears in the sky to be part of the Hyades star cluster, it is not in fact a cluster member, lying only half as far away. \blacktriangleright Table 3.

Alderamin (Alpha Cephei) The brightest star in the constellation Cepheus. It is an \blacktriangleright *A star* of magnitude 2.7. The name, which is of Arabic origin, means ‘the right arm’.

Alfvén waves Magnetic waves that can propagate through an electrically conducting fluid, such as an ionized gas, in a magnetic field.

Algenib (Gamma Pegasi) A \blacktriangleright *B star* of magnitude 2.8 that marks one corner of the \blacktriangleright *Square of Pegasus*. The Arabic name means ‘the side’. The name is also sometimes applied to the star Alpha Persei, more usually known as \blacktriangleright *Mirfak*.

Algieba (Gamma Leonis) A \blacktriangleright *visual binary* star consisting of two yellow giants, separated by 4 arc seconds. The magnitudes are 2.3 and 3.5, and they orbit around each other in a period of 620 years. \blacktriangleright Table 3.

Algol (The Demon Star; Beta Persei) One of the best-known variable star, its magnitude varying between 2.2 and 3.5 in a period of 2.87 days. The variation occurs because Algol is an \blacktriangleright *eclipsing binary* system in which the two stars

regularly cross in front of each other as viewed from Earth. Algol is regarded as the prototype eclipsing binary.

The brighter of the components of Algol is a ► *B star* and the fainter a ► *G star*. The decline in brightness as the G star cuts off the light from its brighter companion takes four hours, and minimum lasts only twenty minutes. The secondary eclipse, when the fainter star causes a dip in brightness of only 0.06 magnitude, is not detectable by eye. Variations in the spectrum of Algol with a period of 1.862 years reveal the presence of a third star in the system.

There is also evidence in the spectrum for ► *mass transfer* between the two close companions, supported by observations that Algol is a radio star, erratically flaring up to twenty times its normal radio brightness. The radio emission is attributed to gas streaming onto the primary star.

Algonquin Radio Observatory A 46-m (150-foot) fully steerable dish in Ontario, Canada, which began radio astronomy observations in 1966. It is now used almost exclusively for geodetic experiments.

alidade A movable sighting arm on an ► *astrolabe* that is used in making observations of the ► *altitudes* and ► *azimuths* of celestial objects.

Alinda Asteroid 887, diameter 4 km. It was discovered in 1918 by Max Wolf when it made a close approach to the Earth. It is a member of the ► *Amor* group.

Alioth (Epsilon Ursae Majoris) The brightest star in the constellation Ursa Major, the Greek letters in this case being allotted in order of position rather than of brightness. Alioth is an ► *A star* of magnitude 1.8. ► Table 3.

Alkaid (Eta Ursae Majoris) A star in Ursa Major, at the end of the bear's 'tail'. It is a ► *B star* of magnitude 1.9. The Arabic name means 'chief of the mourners', for the Arabs saw the constellation as a bier rather than a bear. ► Table 3.

Allan Hills A region in Antarctica from where large numbers of meteorites have been recovered. The meteorites become concentrated in the area by natural movements in the ice sheet, and are relatively easy to identify against the ice.

Allegheny Observatory A research observatory of the University of Pittsburgh, Pennsylvania. The present building dates from 1912 but its predecessor was started in 1858 by several Pittsburgh businessmen. Inspired by Donati's Comet of that year, they formed the Allegheny Telescope Association and acquired a 33-cm (13-inch) refractor. In 1867, the telescope and observatory were given to Western University in Pennsylvania, the forerunner of the University of Pittsburgh. The first salaried director was Samuel Pierpont Langley. He was succeeded by James E. Keeler, co-founder of the *Astrophysical Journal* and subsequently director of the Lick Observatory.

The 1912 building is equipped with three telescopes. The original 33-cm refractor is used primarily for educational and testing purposes. The others are the 76-cm (30-inch) Thaw refractor and the 79-cm (31-inch) Keeler Memorial Reflector. These continue to be used for research.

Allende meteorite A meteorite of the ► *carbonaceous chondrite* type, which fell in Mexico in 1969. More than two tonnes of material fell, scattering over an area 48 by 7 km, making it one of the most massive carbonaceous chondrites known.

all-sky camera A camera with a very wide-angle, fish-eye lens, capable of photographing all or most of the visible hemisphere of the sky on one exposure. Cameras of this type have applications in routine surveys for meteors and artificial satellites.

ALMA Acronym for the ► *Atacama Large Millimeter Array*.

Almagest A large astronomical treatise by the Greek astronomer Ptolemy (Claudius Ptolemaeus), who worked in Alexandria between about AD 127 and 151. The name is an Arabic corruption of a Greek title, 'The Greatest', though Ptolemy's original title was 'The Mathematical Collection'. It ranks among the most important works on astronomy ever written. It included a star catalog and dealt with the motion of the Moon and planets. The rules set out for calculating the future positions of the planets, on the basis of an Earth-centered universe, were used for centuries.

almanac A book of tables giving the future positions of the Moon, planets and other celestial objects, often compiled with additional information of practical value to users. An almanac normally covers the period of one calendar year.

almucantar (1) A circle on the ► *celestial sphere* parallel to the horizon.

almucantar (2) An instrument for measuring ► *altitude* and ► *azimuth*.

Alnath A variant spelling of the star name ► *Elnath*.

Alnilam (Epsilon Orionis) One of the three bright stars forming Orion's belt. The Arabic name means 'string of pearls'. Alnilam is a ► *supergiant* ► *B star* of magnitude 1.7. ► Table 3.

Alnitak (Zeta Orionis) One of the three bright stars forming Orion's belt. The Arabic name means 'the girdle'. Alnitak is a ► *supergiant* ► *O star* of magnitude 1.8. ► Table 3.

Alpha Centauri The brightest star in the constellation Centaurus and the nearest bright star to the Sun, at a distance of 4.34 light years. It is a ► *visual binary* star with an orbital period of 80 years. The two components are of ► *spectral*

types G and K and have a combined magnitude of -0.27 . The 11th magnitude star Proxima Centauri, though two degrees away on the sky, is thought to be associated with this star system because it has a similar motion in space.

Proxima, a dim \blacktriangleright *M star*, is the nearest star to the Sun at a distance of 4.24 light years. Alpha Centauri is also called by the Arabic name Rigil Kentaurus (sometimes Rigel, or shortened to Rigil Kent), which means 'the foot of the Centaur'. An alternative name is Toliman. \blacktriangleright Table 3.

alpha particle The nucleus of a helium atom, consisting of two protons and two neutrons. Alpha particles are emitted by many radioactive isotopes and also play an important role in nuclear fusion processes within stars.

Alphard (Alpha Hydrae) The brightest star in the constellation Hydra. Its Arabic name means 'the solitary one of the serpent'. It is a \blacktriangleright *K star* of magnitude 2.0. \blacktriangleright Table 3.

Alphekka (Gemma; Alpha Coronae Borealis) The brightest star in the constellation Corona Borealis. It is an \blacktriangleright *A star* of magnitude 2.2. The Arabic name, also spelt Alphecca, means 'bright one'. This star is sometimes called by the Latin name Gemma, the 'jewel' in the crown.

Alpheratz (Sirrah; Alpha Andromedae) The brightest star in the constellation Andromeda, marking one corner of the \blacktriangleright *Square of Pegasus*. It was formerly considered to belong to that constellation, being designated Delta Pegasi. Alpheratz is an \blacktriangleright *A star* of magnitude 2.1.

Alphonsine Tables A set of tables giving the positions of the Sun, Moon and planets, published in 1252 under the patronage of King Alphonso X of Castille. They were computed by a team of astronomers using the principles set out by Ptolemy in the \blacktriangleright *Almagest* but incorporating more recent observations. They were in use in Europe for nearly 400 years, until superseded by the work of Johannes Kepler, during which time they were the best available.

Alphonsus A lunar crater, 118 km (73 miles) in diameter. A prominent ridge runs across the center, almost along a north-south line, through a central peak about 1 km high. Temporary reddish clouds were observed there in 1958 and 1959, possibly due to the release of gas from the rocks. \blacktriangleright *lunar transient phenomenon*.

Alpine Valley (Vallis Alpes) A flat-bottomed valley, 150 km (95 miles) long, crossing the lunar Alps and connecting the Mare Frigoris with the Mare Imbrium.

Alps (Montes Alpes) A range of mountains on the Moon, lying between the Mare Frigoris and the Mare Imbrium.

ALSEP Abbreviation for Apollo Lunar Science Experiment Package, experimental set-ups that were deployed on the Moon by astronauts during the manned ► *Apollo program* (1969–72). One was left by every mission except the first. Each automated laboratory was powered by a small nuclear generator. The packages included seismometers to measure moonquakes and experiments to measure the solar wind, detect any trace atmosphere and measure the heat flow from the Moon's interior. All the experiments were turned off in 1978.

Altair (Alpha Aquilae) The brightest star in the constellation Aquila. The Arabic name means 'the flying eagle'. It is an ► *A star* of magnitude 0.8 and one of the closest of the brighter stars at a distance of 17 light years. ► Table 3.

altazimuth mounting A form of telescope mounting in which the two independent rotation axes allow movement of the instrument in ► *altitude* and ► *azimuth*. It is the simplest type of telescope mounting but it is necessary to move the telescope about both axes simultaneously in order to track the motion of celestial objects across the sky. However, the ability to control the motion of a large telescope by computer has led to the exclusive use of altazimuth mountings for new professional instruments. ► *Dobsonian telescope, equatorial mounting*.

altimetry The measurement of height, including techniques such as the determination of the height of planetary features by means of radar.

altitude The direct angular distance between a celestial object and the horizon, measured vertically (i.e. along the great circle that passes through the object and the zenith).

aluminizing The process in which a thin reflecting layer of aluminum is deposited on the optical glass surface of a telescope mirror.

Amalthea A small satellite of Jupiter (number V), discovered by E. E. Barnard in 1892. Images obtained by the ► *Voyager 1* mission showed it as a red-colored, potato-shaped object. The surface is heavily cratered, the largest depression, Pan, being 90 km (56 miles) across. The red color is thought to be due to sulfur compounds blown off the satellite ► *Io*. ► Table 6.

AMANDA Acronym for Antarctic Muon And Neutrino Detector Array, a cosmic neutrino detector consisting of photomultiplier tubes arranged in concentric rings at a depth of several kilometers in the ice. It takes advantage of the clarity of the Antarctic ice at great depths, which is largely free of imperfections. The photomultipliers detect light flashes created when neutrinos occasionally interact with the ice. AMANDA began operation in

1999 with 422 photomultipliers. It is planned to extend the array to 5,000 or more distributed over a cubic kilometer. The project is a collaboration between universities and institutions in the USA and Europe. ► *neutrino astronomy*.

Amazonis Planitia A light-colored plain in the north equatorial region of Mars.

American Association of Variable Star Observers (AAVSO) An organization based in the USA for amateur observers of ► *variable stars*. It was founded in 1911 by William Tyler Olcott, who began making 'volunteer' observations of the brightness of variable stars and sending his results to Edward C. Pickering at Harvard College Observatory after hearing a talk at the American Association for the Advancement of Science meeting in 1909. It has over a thousand members worldwide and a huge database containing millions of individual observations.

American Astronomical Society (AAS) The main US organization for professional astronomers, which was founded in 1899. Its objective is the advancement of astronomy and the promotion of closely related branches of science.

American Ephemeris and Nautical Almanac An ► *almanac* produced by the ► *United States Naval Observatory*, Washington, DC, between 1855 and 1980. In 1981 it was replaced by the ► *Astronomical Almanac*.

Ames Research Center A NASA research establishment located near San Francisco.

AM Herculis star ► *polar*.

Amor Asteroid 1221, diameter 1 km, discovered by E. Delporte in 1932. It is the prototype of the *Amor group* of Earth-approaching asteroids, with perihelion distances between 1.0 and 1.3 AU, taking them inside the main ► *asteroid belt*.

Amphitrite Asteroid 29, diameter 200 km, discovered by A. Marth in 1854.

amplitude The maximum value of the variable quantity or displacement in a wave or oscillation. In astronomy, the term is used particularly to mean the magnitude range of a ► *variable star*.

Am star An ► A *star* that has unusually strong ► *absorption lines* of certain elements in its spectrum, particularly of metals such as iron and nickel, and weak lines of the elements calcium and scandium. These features are thought to result from vertical diffusion that separates out the various elements in the stable outer layers of a slowly rotating star. Am stars are also called *metallic-line A stars*.

AN Common abbreviation for the journal ► *Astronomische Nachrichten*.

analemma The figure-of-eight shape that results if the Sun's position in the sky is

recorded at the same time of day throughout the year. The position of the Sun varies because the Earth's rotation axis is not perpendicular to its orbit around the Sun and because the Earth's orbit is elliptical rather than circular.

Ananke A small satellite of Jupiter (number XII), discovered in 1951 by S. B. Nicholson. ► Table 6.

Andromeda A northern constellation among the 48 listed by Ptolemy (c. AD 140).

In classical mythology, Andromeda was the daughter of Queen Cassiopeia and was condemned to be sacrificed to a sea monster. The figure traditionally associated with the constellation is that of a chained woman. The three brightest stars, Alpha (Alpheratz or Sirrah), Beta (Mirach) and Gamma (Alamak) represent her head, hip and foot, respectively. Andromeda is large but not very conspicuous, known mainly for the ► *Andromeda Galaxy*.

► Table 4.

Andromeda Galaxy (M31; NGC 224) A large ► *spiral galaxy*, visible to the unaided eye as a misty patch in the constellation Andromeda. It lies at a distance of 2.3 million light years and is the largest member of the ► *Local Group*, with a mass of 300 billion solar masses. It is believed that our own Milky Way ► *Galaxy* is similar to the Andromeda Galaxy although it has only half the mass. The spiral structure is not easy to see since the galaxy is almost edge-on, the disk being tilted at an angle of only 13° to the line of sight. In a small telescope, only the small central nucleus is visible though the fainter spiral arms actually extend over three degrees of sky – more than six times the apparent diameter of the Moon. Several dwarf galaxies are in orbit around the Andromeda Galaxy, notably M32 and NGC 205.

Historically, it was the first object whose extragalactic nature was recognized, and it is the most distant object visible to the naked eye.

Andromedids A ► *meteor shower* associated with ► *Comet Biela*, not observed since 1940. The first recorded appearance of the shower, which radiated from near the star Gamma Andromedae, was in 1741. Spectacular meteor storms were observed in November 1872 and 1885, following the break-up of the associated comet, when the rates were many thousands per hour. The shower is also known as the *Bielids*.

Angelina Asteroid 64, diameter 60 km, discovered by E. W. Tempel in 1861. It is one of the most strongly reflecting asteroids known, with an albedo of 34 per cent.

Anglo-Australian Observatory (AAO) An observatory at the ► *Siding Spring Observatory* site in New South Wales, Australia, with a laboratory in Epping (a suburb of Sydney). It is funded jointly by the governments of Australia and

the UK. The observatory is administered by the Anglo-Australian Telescope Board (AATB), which was set up in 1971 when the 3.9-m (150-inch) ► *Anglo-Australian Telescope* was being constructed. In 1988, the AATB took over operational responsibility for the 1.2-m (48-inch) UK Schmidt telescope, which has been at the site since 1973, and it also became a fully shared facility at that time.

Anglo-Australian Telescope (AAT) A 3.9-m (150-inch) reflecting telescope, owned and funded jointly by the governments of Australia and the UK. It is situated at the ► *Siding Spring Observatory* site in New South Wales, Australia. The telescope was constructed in the early 1970s on an equatorial horseshoe mounting, and started scheduled observing in 1975. It was the first telescope to be fully computer controlled.

ångström (symbol Å) A unit of length used particularly for the wavelength of light, equivalent to 10^{-10} m or 0.1 nm. It was formerly used universally for expressing the wavelength of light but, in the SI system of units, the use of nanometers is now preferred.

angular diameter The apparent diameter of an object in angular measure, i.e. radians, degrees, arc minutes or arc seconds. Angular diameter is determined by the combination of true diameter and distance.

angular distance The length of an arc expressed in angular measure (i.e. radians, degrees, arc minutes or arc seconds) as the angle subtended by the arc at the observer. The angular distance between two points on the celestial sphere, for example, is in effect the angle between imaginary lines from the observer in the directions of the two points.

angular momentum A property analogous to ► *momentum*, that a body or system of bodies possesses by virtue of its state of rotation or orbital motion. An object with angular momentum will continue to rotate at the same rate unless a torque (i.e. a turning force) acts on it. Within a closed system, on which no outside torques act, the total angular momentum remains constant even if there are changes in the way it is distributed internally. It is a vector quantity, the direction of which is along the axis of rotation or, for orbital angular momentum, along a line perpendicular to the orbital plane.

angular velocity The rate at which a rotating body sweeps out angle. Angular velocity may be measured in radians, degrees or revolutions per unit time.

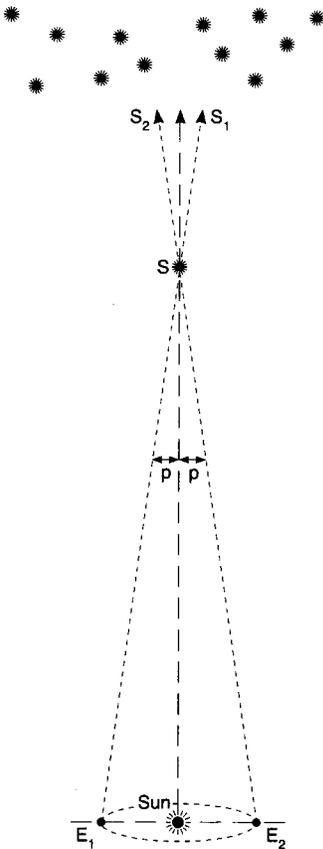
anisotropy The absence of ► *isotropy*. The properties of an anisotropic object or system are dependent on direction.

annual parallax

annual aberration ► *aberration of starlight.*

annual parallax (heliocentric parallax) The difference between the position of a star as seen from the Earth and that seen by a hypothetical observer at the Sun. The effect of annual parallax is observed as a shift in the positions of relatively nearby stars against the background of more distant ones during the Earth's yearly journey in orbit around the Sun. If the position of a nearby star is plotted over a year, it appears to sweep out an ellipse on the sky, called the *parallactic ellipse*.

The annual parallax is formally defined as the difference in position that would be measured by hypothetical observations made from the center of the Earth and the center of the Sun.



Annual parallax. E_1 and E_2 mark the location of the Earth in its orbit on two dates six months apart. Over the six months, the apparent position of star S changes from S_1 to S_2 , an angular displacement equal to twice the annual parallax, p . (Not to scale.)

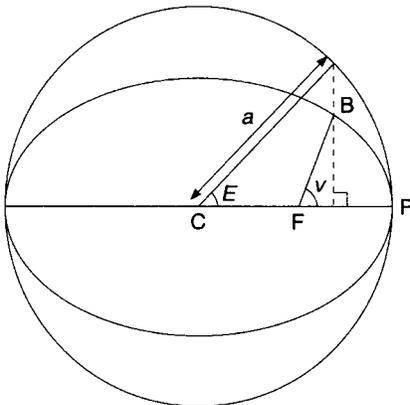
annular eclipse

annular eclipse A solar \blacktriangleright *eclipse* in which a ring of the Sun's photosphere remains visible when the Sun, Moon and Earth are aligned. Since the orbits of the Earth around the Sun and of the Moon around the Earth are elliptical, the \blacktriangleright *angular diameters* of the Sun and Moon vary slightly as their distances from the Earth change. A solar eclipse that would otherwise have been total is seen as annular if the Moon's angular diameter at the time is less than the Sun's.

anomalistic month The time taken by the Moon to orbit the Earth from \blacktriangleright *perigee* to perigee, equal to 27.554 550 days. \blacktriangleright *month*.

anomalistic year The time between successive passages through \blacktriangleright *perihelion* by the Earth in its orbit around the Sun. Its length, 365.259 64 days, is greater than that of the \blacktriangleright *tropical year* by about 27 minutes because of the gradual change in position of the perihelion point.

anomaly An angle used in describing the motion of a body in an elliptical orbit. The *true anomaly*, v , is the angle between the line joining the body B to the principal focus of the ellipse, F, and the line joining F to *periapsis* the point on the orbit closest to F (see illustration). The *mean anomaly*, M , is the angle between the line PF and the line joining F to a hypothetical body that has the same orbital period as the real one under consideration but travels at a uniform angular speed. The *eccentric anomaly*, E , is a useful parameter for expressing the variable length of the radius vector, r . The linking equation is $r = a(1 - e \cos E)$ where a is the semimajor axis and e the eccentricity of the elliptical orbit. The relationship between M and E , $M = E - e \sin E$, is known as *Kepler's equation*.



Anomaly. The true anomaly, v , and eccentric anomaly, E , of a body at B.

- anorthosite** An igneous rock, consisting primarily of the silicate mineral plagioclase. It is an important constituent of the highland regions on the Moon.
- ANS** The first Dutch national satellite (Astronomische Nederlands Satelliet), launched on August 30, 1974. It carried experiments in ultraviolet and X-ray astronomy.
- ansae** (sing. *ansa*) The Latin word meaning ‘handles’, used to describe the appearance created by the protrusion of the rings of ► *Saturn* either side of the planet’s disk, as viewed through a telescope.
- antapex** The point on the celestial sphere in the diametrically opposite direction to the solar ► *apex*. The whole solar system is moving directly towards the apex and away from the antapex relative to stars in the Sun’s vicinity. The antapex lies in the constellation Columba (at about RA 6h, Dec. -30°).
- Antarctic Submillimeter Telescope and Remote Observatory (AST/RO)** A 1.7-meter submillimeter-wave telescope in operation at the US Amundsen–Scott South Pole Station since January 1995, where it can take advantage of the exceptionally cold and dry atmospheric conditions. ► *submillimeter-wave astronomy*.
- Antarctic Muon And Neutrino Detector Array** ► *AMANDA*.
- Antares** (Alpha Scorpii) The brightest star in the constellation Scorpius. It is a red ► *supergiant* ► *M star* of magnitude 1.0. The name is derived from Greek, meaning ‘rival of Mars’ – a reference to its noticeable color. It is a ► *semiregular variable* star, fluctuating between magnitudes 0.9 and 1.1 over a five-year timescale. It has a sixth magnitude blue companion only 3 arc seconds away. ► Table 3.
- ANTARES** An array of detectors for cosmic neutrinos on the floor of the Mediterranean Sea 40 km south-east of Marseille. The project is an international collaboration involving France, the UK, the Netherlands, Russia and Spain.
- antenna** (aerial) Any device for collecting or transmitting radio signals. The design depends on the wavelength and strength of the signal. The simplest form is a straight rod, or dipole; the commonest type used in radio astronomy is a paraboloid dish. A simple telescope may use just a single antenna. ► *Radio interferometers* may consist of an array of many individual antennas.
- Antennae Galaxies** A popular name for the pair of interacting galaxies NGC 4038 and 4039. The name arises from two long, curved streamers of stars, created when they collided. The galaxies are 48 million light years away and the streamers about a hundred thousand light years long.

antenna temperature

antenna temperature A parameter used in radio astronomy as a measure of the power per unit bandwidth (p) of the signal received by an antenna after losses in the detector system. It is defined as p/k , where k is ► *Boltzmann's constant*.

anthropic principle The recognition that only a limited number of all the theoretically possible universes are favorable to the emergence of life. In theory, a large range of universes with different physical properties and values of the constants of nature could exist. The anthropic principle states that only a restricted class of such models can have intelligent observers. Since we exist, the universe we inhabit must have characteristics within the narrow range that has permitted our evolution. This basic expression of the anthropic principle is not generally regarded as controversial, and is sometimes called the *weak anthropic principle*.

The so-called *strong anthropic principle*, proposed by Brandon Carter, is more speculative. This asserts that, because there are so many apparently unconnected coincidences in nature, which together have made it possible for life to develop, the universe *must* give rise to observers at some stage in its development.

anticyclone A region in a planetary atmosphere in which pressure increases towards the center.

antimatter Matter composed of elementary particles that have masses and spins identical to those of the particles that make up ordinary matter, but with many other properties, such as electric charge, reversed. Although some *antiparticles* are observed in nature and others are produced in the laboratory, there is no evidence for the existence of large amounts of antimatter, for example, in the form of 'antihydrogen'. If ordinary matter and antimatter were to meet, they would annihilate each other with the release of energy.

Antinoüs Asteroid 1863, diameter 3 km. It was discovered by A. Wirtanen in 1948, when it made a close approach to the Earth, and was recovered in 1972.

antitail Part of a comet's ► *dust tail* which appears to protrude forwards towards the Sun from the comet's head, sometimes like a spike. The effect is one of perspective, due to the relative positions of the Earth and the comet, which determine the angle at which the curving dust tail is viewed.

Antlia (The Air Pump) A small, faint southern constellation introduced in the mid-eighteenth century by Nicolas L. de Lacaille. It was originally called Antlia Pneumatica. ► Table 4.

Antoniadi scale A scale of five points, devised by the French astronomer Eugenio Antoniadi (1870–1944) and widely used by amateur astronomers for